VOL. 3 NO. 1 January 1986

COMPUTER DIGEST

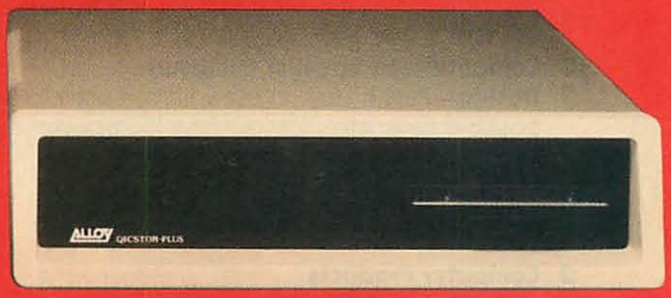
A NEW KIND OF MAGAZINE FOR ELECTRONICS PROFESSIONALS

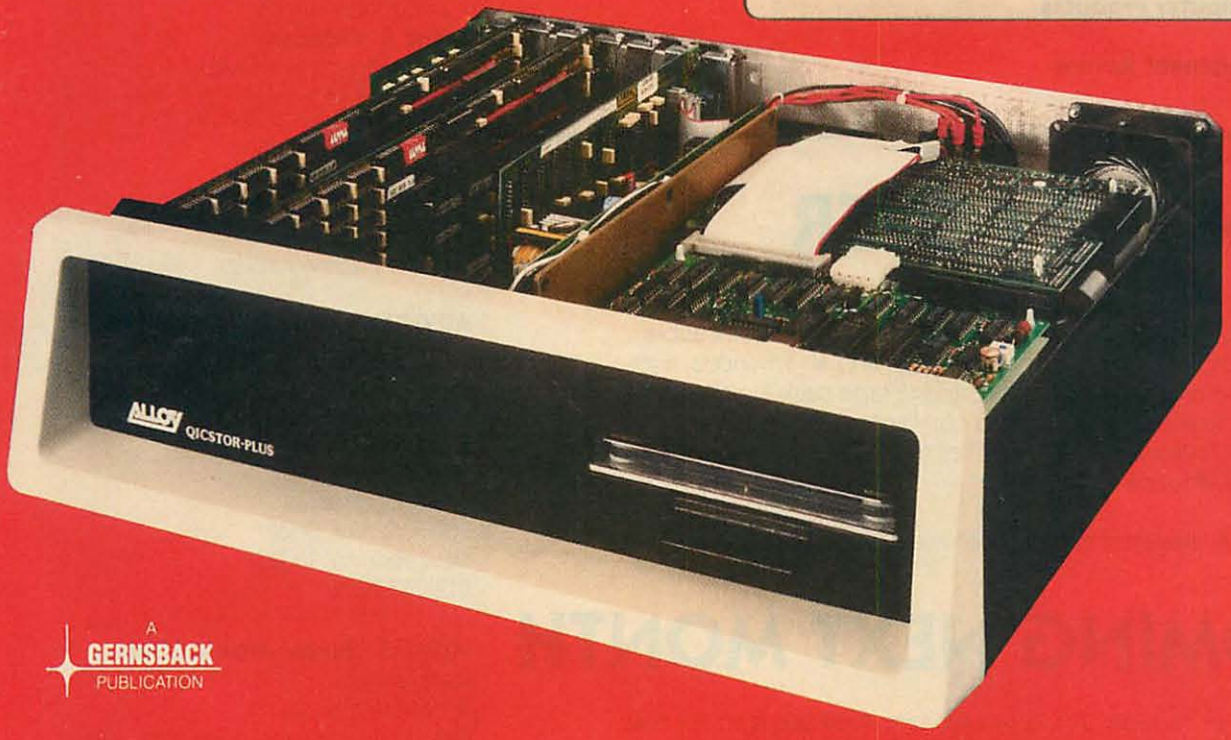
HARD DISK TECHNOLOGY

An In-Depth Review Of The State Of The Art.

555 TIMER DESIGNS

Use Your Computer To Select Components.





A GERNSBACK PUBLICATION

LOUDSPEAKER ENCLOSURE DESIGN

Use Your Computer to Optimize Enclosure Dimensions.

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ON THE COVER

Alloy's QICSTOR-PLUS is a personal computer subsystem that integrates five additional IBM™ Personal Computer compatible expansion slots, high-capacity hard disk and an advanced, high-speed file-oriented streaming cartridge tape backup unit. It fits under a personal computer and combines a 5¼ Winchester hard disk with formatted data capacities from 30MB to 110MB on a single 600-foot cartridge.

™IBM is a registered trademark of International Business Machines.

COMING NEXT MONTH

Look for an in-depth article on Monitors. After you read this one, you'll be far-better prepared to talk to that computer-store salesman! We'll also have the last part of the two-part article on using your computer to help design loudspeaker enclosures, . begun this month, and we'll be starting a three-part article on a hi-res graphics adapter for your Apple II.

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LETTERS

Warning!

The October, 1985 issue had an article by Elliott S. Kanter entitled "Saving Your Delicate Electronic Equipment." I was compelled to write to you at once. General Electric says, "Varistors initially fail in a short-circuit mode when subjected to surges beyond their peak current/energy ratings... When the device fails in the shorted mode, mechanical rupture of the package accompanied by expulsion of package materials in solid and gaseous form can occur. The potential hazard can be minimized by fusing the varistor to limit high fault currents, or by locating the varistor in a shielded container and away from other components"—S. R. B. Ft. Geo. Meade, MD.

Thank you for bringing this to our attention.

No Sale

I don't know anything at all about computers, but I'm willing to learn. If you will provide me with a decent computer system, I'll write an article about how I learned to compute. How much would you pay for such an article. Would you be interested? J. P., Kansas City, KS.

No.

Timex

Timex/Sinclair 1000's used to be everywhere and now I can't find a thing on them. How about peripherals? Did they just disappear?—G. S., Cheektowaga, NY.

I'm afraid they've gone the way of the Reo, the Cord, and the Studebaker. But it was a good computer, low enough in cost so that you didn't mind experimenting with it. Like you, I wish that somebody would bring it (or one like it) back again!

555 Timer

Can you provide some additional information on the 555 timer? It seems to keep cropping up everywhere and I'd like to learn more about it. R. D., Waco, TX.

See page 8 of this issue!

More Space!

I've noticed in recent issues that **ComputerDigest** is not as large as it used to be. I'd like to know if there's anything I might do to help get it expanded again? R. W., Cincinatti, OH.

Hey! Now that's a good idea. Why don't you write a letter to our publisher and tell him you miss those extra pages. ◀CD▶

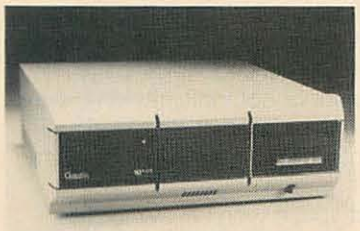
COMPUTER PRODUCTS

For more details use the free information card inside the back cover

TAPE-DRIVE OPTION, is a 10-megabyte tape cartridge drive, designed for the *CompuPro 10 Plus* multi-user microcomputer system.

Built directly into the *CompuPro 10 Plus* enclosure, the tape drive replaces one of the floppy-disk drives and has a "start/stop" feature that allows users to backup selected files. The option is also available as an upgrade for users with already installed *CompuPro 10* and *CompuPro 10 Plus* systems.

The tape-drive option can be ordered simultaneously with a *CompuPro 10 Plus* and is priced at $825. As an upgrade, the tape drive has a list price of $1095.00.—*Viasyn Corporation,* 450 Newport Center Drive, Suite 200, Newport Beach, CA 92660.



CIRCLE 11 ON FREE INFORMATION CARD

PERSONAL COMPUTER, the Tandy model *1200 HD,* is functionally identical to the IBM model *PC/XT,* using the same software and option cards. It is designed for business customers who require much higher speed, more detailed graphics, more memory, and more disk capacity than is possible with the model *PC/XT.*

Standard features of the model *1200 HD* computer parallel those of the model *PC/XT* by providing a single 360K full height, double-sided, double-density 5¾ inch floppy disk drive and a 10-MB hard disk drive housed in the desktop unit. The 84-key detachable keyboard with tilt legs has the same layout as in the model *PC/XT,* with improved placement of the keys and other valuable features. The model *1200 HD* is priced at $2999.00.—**Tandy Corporation/Radio Shack,** 1800 Tandy Center, Fort Worth, TX 76102. ◀CD▶

CIRCLE 12 ON FREE INFORMATION CARD

SOFTWARE REVIEW

TYPERITE— $49.00

Now you can get rid of your typewriter!

■when the new girl came into the office, she looked balefully at the computer terminal. "I don't know how to work a computer," she said hesitatingly. "Don't worry about it," we assured her. "This one is different." By lunchtime, she didn't want to leave her new-found love even to go out for a cup of coffee. Why? Because the *TYPERITE* software from Selfware makes your computer so like a memory typewriter, that even the most-raw beginner will interface with a computer with no trouble at all! And once you've developed a facility with it, which might take all of fifteen minutes or so, you'll be looking around to find a place for your typewriter. You aren't going to be needing it anymore.

What makes this software so appealing is the graphic display that is presented to the operator. Along the bottom of your CRT screen, you get representation of the top of a typewriter. It's actually what a typist sees when using an ordinary non-computerized typewriter. The result is a warm, comfortable feeling of security that takes away some of the stigma attached to learning something radically new. What's more, this representation is indeed functional as well. It's not just fancy graphics put up there as a part of the display.

While this system may have originally been designed to facilitate routine typing work on the computer, we've found that it also makes an excellent bridge for people who have been trained on typewriters and are now faced with the problem of learning to operate a computer. However, its value extends far above and beyond that.

But let's get down to the nitty-gritty. With *Typerite* you can easily address envelopes and fill out forms using your computer. The new computer user experiences immediate and positive results. And you can actually type a letter and spend your brain time thinking about what you want to say instead of worrying about complicated computer commands and involved word processing.

Hard to use? Not at all. Put the disk in your disk drive, type the letters TR and hit the carriage return. Just follow the easy-to-understand instructions on the screen. You actually *see* a representation of a typewriter carriage on the screen and can quickly and easily set tabs, margins, underline, and center text. It works with all printers and with no special installation procedures

Typerite has two operational modes, standard and document. In both modes, you type a single line, review and/or change the line, and when you are satisfied, hit return and the line gets printed. The difference between the two modes is that in document, the software saves what you write.

With *Typerite* you can quickly and easily fill out forms. Simply type the necessary information in just as you would have with a typewriter. Using document, you can set up a template for your form. The template is simply a document that you create with "stop marks" at the places where you want to add information to the form. When you print out, the system stops at each stop mark and waits for you to type what is to be printed on the form. Once you set it up, you can use the template again and again.

Some of *Typerite's* features include: (in the standard mode) Save seven different margin and tab settings, set margins, set and clear a tab, clear all tabs, margin release, bell ring before end of margin, set tab every five spaces. It provides backspace/delete, cursor movement within a line, switch between insert and overtype, center between margins, single or double spacing, underlining and page eject.

In the Document Mode, you have all standard typerite features and can create forms templates, save documents as file, stop marks to allow data entry during printing, print a document line-by-line while creating or turn print off, save initial margins and tabs, save underlines or page ejects. You can change saved margins and tabs, delete or add underlines, page ejects and stop marks, print or not while revising, store with same name or new name, stop at stop marks to allow typing during printing, abort printing at any time, or abandon revisions.

There's a lot more that space won't allow for. For more information, contact Selfware, 3545 Chain Bridge Road, Fairfax, VA 22030.◀CD▶

HARD DISK DRIVES

A hard disk...And all that memory!

Marc Stern

■Every computer hobbyist faces a time when his needs outgrow his mass storage system. That's when the cassette recorder gives way to the floppy disk and the floppy to the hard or fixed disk. Each new storage medium offers the user a leap in speed and capability.

For example, the typical cassette holds about 500K of information sequentially, but, its data transfer rate is a slow 1200 to 2400 bits per second. A user becomes tired of this slowdown and the lack of random access. He must go through file after file to find the one he wants on the tape.

The next step is the floppy disk and, although some forms have less capacity—190K—they make up for it in speed and random access. Programs that took minutes to load and run with the cassette take only seconds to a minute or two to load and run. Instead of searching through a tape, looking for information, the floppy disk's read-write head sweeps across the surface of the diskette and finds the data in seconds.

Hard disks revealed

Also known as a fixed disk, the hard disk's attraction is its information density. A couple of years ago, the standard hard disk in the microcomputer world was the 5-megabyte unit. Today, the minimum disk density is 10 megabytes, with 20-megabyte units available.

When you compare the capacities of floppies and hard disks, you *can* see the hard disk wins. Today's double-sided, double-density floppy disk holds about 360,000 bytes of data, while the hard disk holds 10 million bytes. This means it would take 28 or more floppy disks to hold the same amount of information. The access time—the amount of time it takes to find a specific sector of information on a hard disk—is on the order of 35 to 85 microseconds, while a floppy's time can run in the 20 to 40 millisecond range. Its a quantum jump in information retrieval speed.

There are high-density floppy disks on the market, capable of holding 1.25 megabytes of data, but, they are expensive—some running as much as $850 to $1000—and they still don't hold the sheer bulk of which a fixed disk is capable.

These points make the hard disk much more attractive as a mass storage device. Hard disks aren't portable—there are some cartridge hard disk models which allow you to change disks, but their reliability is still in question—and you must backup the hard disk for insurance, which can take as many as 30 floppy disks and can take the better part of a day. But most small-computer users feel the speed and information density advantages outweigh the latter aspects.

Let's look more closely at a typical hard disk for a better understanding of this technology. If you look closely at Fig. 1, you'll see the typical 5.25-inch hard disk drive—now the standard size in the microcomputer world—contains one or more platters or rigid disks, each of which has its own read-write head.

Most disks today are constructed on an aluminum base, whose surface is covered with a paste containing gamma-ferric oxide particles. This layer is cured and polished and then covered with a Teflon-based lubricant. The entire layer is then burnished smooth. The platters are enclosed in a sealed box which also includes air filtering to keep the surfaces free of contaminants which could cause a head crash and damage the disk.

Thin-film plated disks also use an aluminum substrate. However, rather than being coated with the oxide paste during construction, they are dipped in a series of plating solutions and the platter is coated with thin films of metallic material. The top layer, where the data storage and transactions take place, is a cobalt alloy, which can be as thin as three microinches.

A thin-film sputtered disk takes the aluminum platter through another process. The aluminum platter is coated with a nickel phosphorus layer, which is then polished. Then, using the sputtering processing—a continuous vacuum deposition process—magnetic layers are laid down on the disk. In this way, layers as thin as two microinches can be deposited.

The importance of the type of material on the platter can hardly be understated because it relates to the information density of which the hard disk is capable.

As the platter's coating becomes thinner, the disk is capable of greater information density for a given diameter. Therefore, the thin-film plated and sputtered disks are capable of greater information densities than the oxide-coated disk.

This advantage extends to another area which also affects disk information density, the read-write head. Unlike floppy disk read-write heads which literally

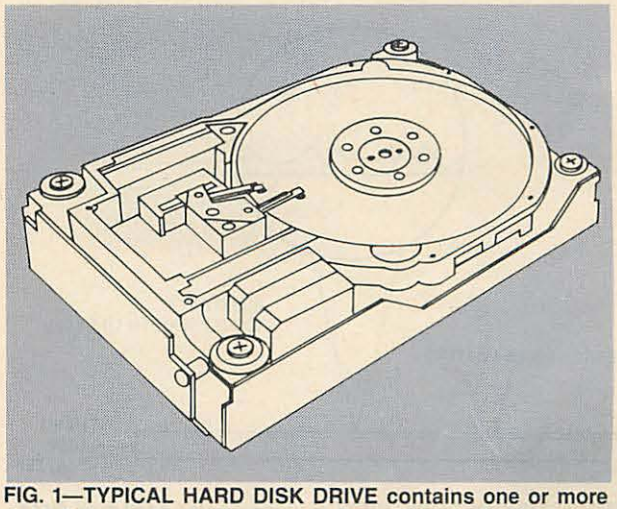


FIG. 1—TYPICAL HARD DISK DRIVE contains one or more rigid disks made of aluminum substrate coated with a magnetic material.

touch the surface of a disk, the read-write heads of a fixed disk fly above the surface on a layer of air. The closer the head skims along the surface the greater the information packing capability. The ability to fly near the surface of the plate is directly affected by the smoothness of the surface.

If you were to look at the oxide-coated surface of a traditional hard disk, it would look smooth. However, a microscopic examination of it would reveal that it is filled with peaks and valleys. (See Fig. 2) The same is true for a plated hard disk.

The read-write head must run as much as 8 microinches off the surface of this type of disk to prevent the head from coming into contact with those peaks.

By contrast, the sputtered disk is so smooth that the head can fly as little as two microinches off the surface, which means its data density can be greater. Thus, it's possible to achieve data densities of up to 20 megabytes on 5.25-inch hard disks.

Head examined

Another critical factor in hard disks is the read-write head itself.

Typically, the read-write head is like that found in a cassette recorder, it is a ferrite unit. The nature of this head effectively constrains the information transfer speed and density of which the fixed disk is capable. A more recent development in read-write heads, the thin-film electromagnetic head, allows the fixed disk to read information more quickly and in greater density than the conventional ferrite read-write.

The head's construction also affects its speed capability and long-range reliability. Look at Fig. 3 and you can see the number of pieces which make up the fixed disk's so-called Winchester arm. It carries the read-write head. From its construction—side rails, load beam and slider—you can see how complicated the mechanism is. This contributes to its aerodynamic inefficiency and affects the speed at which it can fly across the disk surface. The number of moving parts also makes this mechanism more prone to wear.

A newer development—the Whitney arm—promises higher speeds and consequently greater data packing and transfer rates. More efficient aerodynamically (See Fig. 4) it has several advantages over the mechanisms used today.

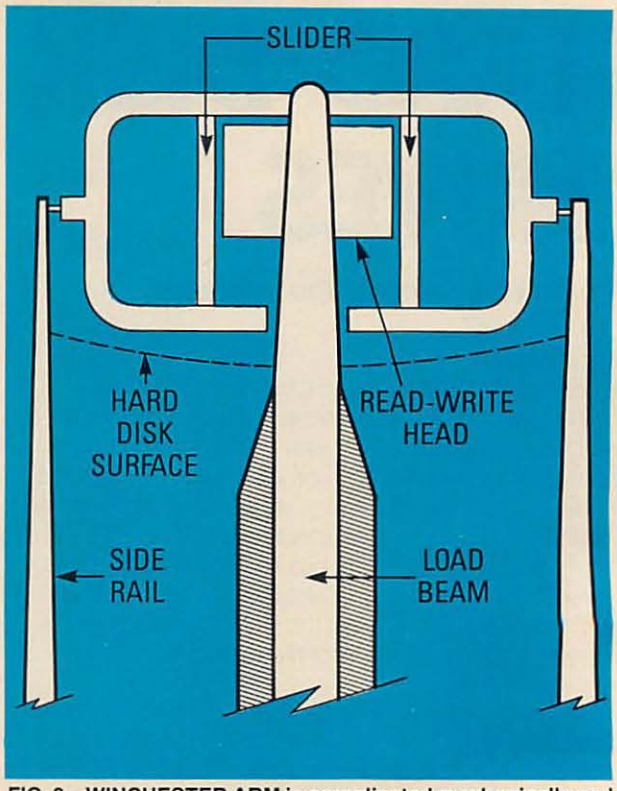


FIG. 3—WINCHESTER ARM is complicated mechanically and aerodynamically. It is less efficient than the Whitney arm.

Speed demon

This adds up to a capable unit which has another innate advantage over just about any other form of mass storage, high speed.

With a rotational speed of 3,600 revolutions per minute, the hard disk drive has a tenfold advantage over the standard floppy disk's 300 to 360 rpm.

This means programs which normally take a minute or two to load and run from a floppy disk will load in seconds. Huge data files will be stored in seconds.

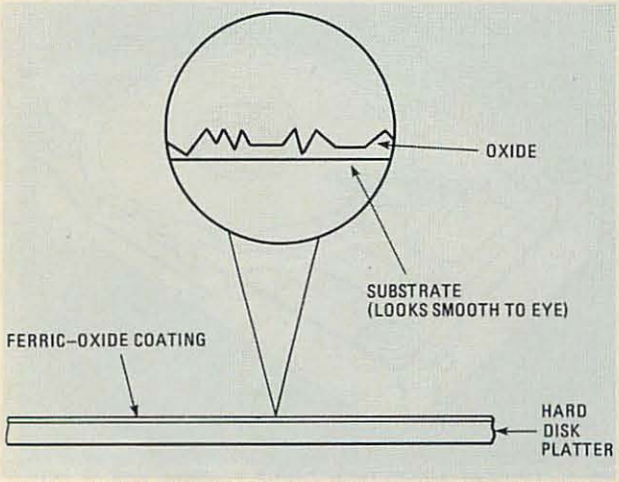


FIG. 2—MICROSCOPIC VIEW of oxide-coated hard disk. Note peaks and valleys in coating (not to scale).

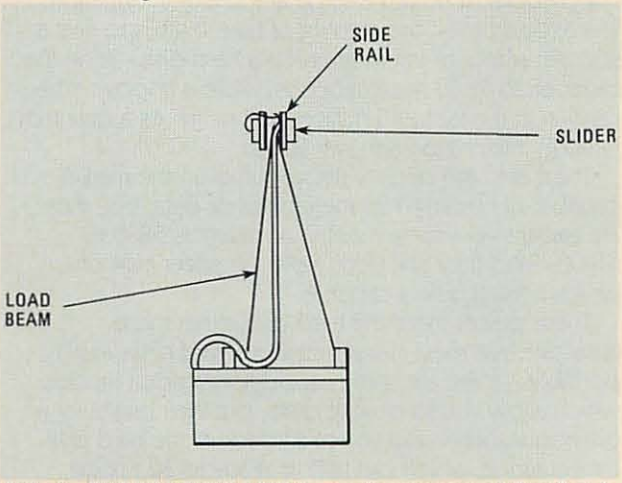


FIG. 4—THE WHITNEY ARM is much more streamlined and efficient.

And data can be manipulated quickly.

With this type of speed, you need a precise read-write head positioning mechanism and there are currently two types used, the open-loop stepper motor and the rotary voice coil positioner.

The open-loop stepper motor is a mechanical system which relies on the stepper motor for precise head positioning. In action, the open-loop stepper motor works with the commands issued by the hard disk controller circuitry. When a program makes a request for data, the circuitry issues a command to the head positioning system which instructs the motor to move the head to a certain track on the disk. As it begins to move, the stepper motor clicks off the number of tracks until it reaches the required spot.

The chief drawback of this method is wear over the long term. The mechanical parts wear and exact head positioning becomes more difficult and data access times become longer.

The voice coil system relies on closed-loop positional feedback for head positioning. In action, the system works in conjunction with information contained either in a special buffer area on the hard disk or in each track to locate a particular track and sector. This information tells the head-positioning circuitry its location in relation to the specific spot the system is seeking and the head uses this information as it moves to the spot. Since it has fewer moving parts than the stepper motor system, it is more reliable than the conventional stepper motor. Its chief drawback is in increased cost.

Read the specifications

With all the foregoing information, there are still several other items to think about, especially if you're in the market for a hard disk. The first is average access time and the second is latency. The first is actually a function of the second.

Average access time refers to the amount of time it takes for the read-write head to move from one piece of data on a hard disk to another. It is a function of the latency or rotational delay of the high-speed hard disk.

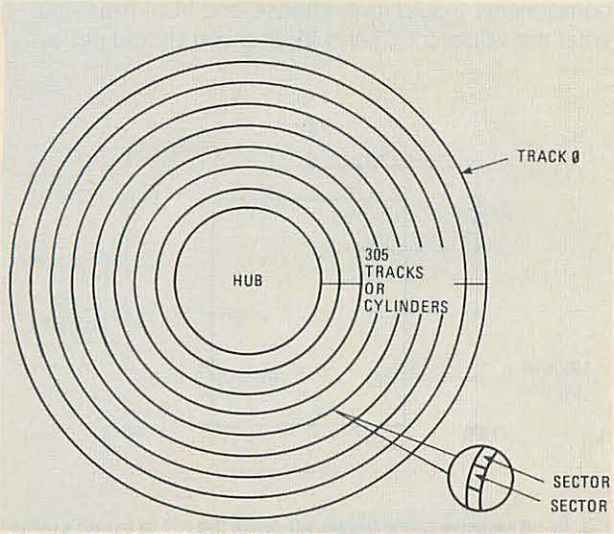


FIG. 5—TRACKS ON HARD DISK are laid out concentrically. Track 0 is used for positional and other data.

Average access time also varies from hard disk to hard disk and with the type of head positioning arrangement used.

Another specification which can prove confusing is the data transfer rate. It is the speed at which data moves from between the hard disk controller and the drive. Most manufacturers quantify this in terms of bits per second of data transfer and some hard disks can have a transfer rate of up to 5 million bits per second. To lessen confusion, you can compare this to the baud rate of a serial communications device, although its speed is manifestly higher.

Disk organization

The final piece of the hard disk puzzle is the organization of the disk. To help put this into perspective it is useful to picture the hard disk as a phonograph record.

Each hard disk is divided into a series of tracks. (See Fig. 5) A typical 10 megabyte hard disk has 305 tracks for information, each of which contains 34,816 bytes of information. Like the grooves in a phonograph record, the tracks are laid out concentrically on the disk's surface, with each track concentric to the one inside it. Unlike a record, the tracks are separate, while the grooves are actually interconnected.

Each track on the disk surface is divided into specific sectors. An index sensor indicates the start of each track.

In action, the hard disk controller head looks first at Track 0—at the outside of the disk—rough positional information and then hunts for the specific track on the disk containing the information which has been requested. When it arrives at the right track, it hunts for the sector containing the header data for that particular file. The header is the identification mark for the file. The head then reads that identification mark, determines where the rest of the information is stored and moves along from sector to sector assembling it. When it has finished, it's ready to use.

The 5.25-inch standard

When hard disks were first introduced more than a decade ago, they were huge, routinely 14 inches in diameter. They didn't make their appearance in the microcomputer world until about four years ago when the first 5.25-inch hard disks were sold. These early disks were only 5 megabyte affairs and it looked for a time as if these would become the standard of the microcomputer world. But, times quickly changed.

Within a year or so, 10-megabyte 5.25-inch hard disk drives began to appear and within another year, these units became the standard as the lower density disks began to disappear from the scene.

About the only thing which was common to the two units was their size. Both were 5.25-inch units, which is still the most common size for a hard disk unit.

Times are changing on this front, too, as 3.5-inch drives make their appearance. Further, even the standard sized drive is changing as it is becoming thinner and half-height drives, capable of 10 and 20 megabytes of data storage are appearing.◀●▶

555 DESIGN PROGRAM

Use your computer to shortcut those tedious 555 oscillator design problems.

Jeff Holtzman

■Some design chores in the electronics lab are quite repetitive, and after the 1000th time we think, "there must be a better way!" Well, if you have a personal computer in your lab, here's a little program that will reduce the tedium of one such chore: Designing 555 monostable and astable oscillator circuits. It's fast, allowing you to make several "runs" quickly, so you can see the effect different component values will have on circuit operation.

Our program will help you determine resistor and capacitor values for the standard circuits shown in Fig. 1a and 1b. The program has been written in MBASIC-80, and it should run as-is on just about any personal computer. We also include several suggestions for improving the program, if you have a taste for such experimenting.

What the program does

When you run the program it asks you to choose between Astable and Monostable circuits (or you may just Exit). If you choose Astable, the program then asks you the frequency you will be working with. Next, you're presented with a menu (lines 220-320) allowing you to choose which parameter you want to work with. Choices 1 and 2 calculate values for R2 and C1, respectively, assuming a value of 1K for R1, and a value entered by you for the third component—C1 and R2, respectively. We chose a default value for R1 of 1000 ohms, but if that doesn't suit your fancy, feel free to change it.

Choice 3 also calculates a value for C1, but here no assumption is made regarding the value of R1: You must enter the values for both resistors. Choice 4 allows you to calculate the frequency that will be obtained; and with that choice, you enter the value for all three components. That allows you to try values for components you can actually buy—which probably won't be the same as the ones calculated above—to see what frequency will result.

For example, suppose you need a 1 kHz oscillator. Suppose further that you happen to have a junk box full of .01 disks that you want to use. Well, run the program, enter "1000" at the "Frequency?" prompt, choose the first item, and enter ".01" at the next prompt. The program will tell you that you need a resistor of 71,500 ohms for R2. The closest standard value is 72,000 ohms, so choose item 4. Entering values of .01, 1000, and 72,000 yields a frequency of about 993 Hz—pretty darn close! In fact that's an error of 7/1000, or .007%. Not bad. Of course, that's only a calculated value; chances are the components you use won't have exactly their nominal values. For more accuracy you could use a 47K resistor in series with a 50K trimmer, and adjust the 555's output with a frequency counter.

The monostable circuit works on a similar basis, but is even simpler, since there are only three variables to take account of: The duration of the trigger pulse, and the values of R1 and C1. The menu (shown in lines 580-710) has three choices. Each asks for two values and then calculates the third. For example, assume you need a pulse one second wide, and that you want to use a 1 μF capacitor. You want to find the appropriate resistor to use, so choose two from the menu. You should get an answer of 909091 ohms. The closest standard value is 1 Megohm, so to find the time those components would give, choose one from the menu, enter the values for C1 and R1, and you should get an

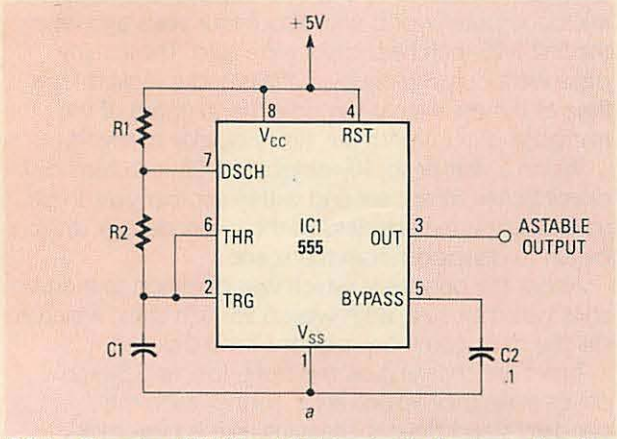


FIG. 1a—The value of R1, R2 and C1 determine the frequency of oscillation of this circuit, and the program simplifies calculating the values of those components.

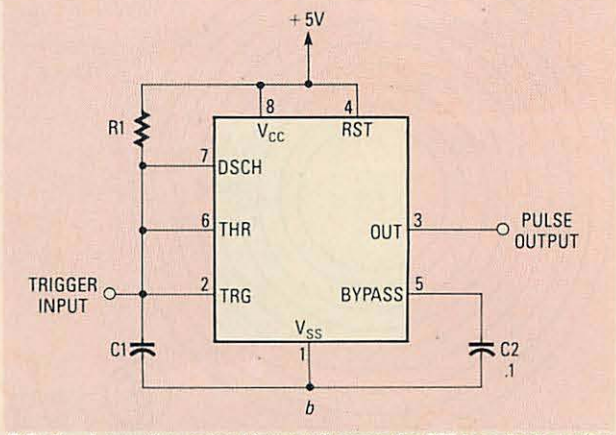


FIG. 1b—A negative-going trigger wil cause the 555 to output a pulse with a width determined by the values of R1 and C1. The program simplifies calculating the values of those components.

```
100 REM 555 timer calculations
    for RE mag.  jkh  3 August
    1985
110 FOR I=1 TO 24:PRINT:NEXT I
120 PRINT "555 Timer
    Calculations   jkh   3
    August 1985"
130 PRINT:PRINT:PRINT:PRINT:
140 INPUT
    "Astable/Monostable/Exit
    (A/M/E)? ", IN$
150 IF IN$="E" OR IN$="e" OR
    IN$="" THEN END
160 IF IN$= "M" OR IN$="m" THEN
    GOTO 580
170 IF IN$="A" OR IN$="a" THEN
    GOTO 190
180 GOTO 140
190 REM do astable calculations
200 PRINT
210 INPUT "Frequency? ",F
220 PRINT
230 PRINT "0.  END"
240 PRINT "1.  FIND R2, GIVEN
    R1 = 1000, C1 = USER ENTRY"
250 PRINT "2.  FIND C1, GIVEN
    R1 = 1000, R2 = USER ENTRY"
260 PRINT "3.  FIND C1, GIVEN
    R1 = USER ENTRY, R2 = USER
    ENTRY"
270 PRINT "4.  FIND F, GIVEN
    C1, R1, R2 USER ENTRIES"
280 PRINT
290 INPUT "    CHOOSE: ",IN
300 PRINT
310 IF IN=0 THEN GOTO 140 ELSE
    ON IN GOSUB 330, 390, 450,
    510
320 GOTO 220
330 REM FIND R2 GIVEN R1=1K, C1
    ENTERED
340 R1 = 1000
350 INPUT "C1 = ",C1
360 R2=(1.44/(F*C1/1E+06)-R1)/2
370 GOSUB 870
380 RETURN
390 REM FIND C1 GIVEN R1=1K, R2
    ENTERED
400 R1=1000
410 INPUT "R2 = ",R2
420 C1=
    1.44/(F*(R1+2*R2))*1E+06
430 GOSUB 870
440 RETURN
450 REM FIND C1 GIVEN R1, R2
    ENTERED
460 INPUT "R1 = ",R1
470 INPUT "R2 = ",R2
480 C1=1.44/(F*(R1+2*R2))*1E+06
490 GOSUB 870
500 RETURN
510 REM FIND F GIVEN C1, R1, R2
    ENTERED
520 INPUT "C1 = ",C1
530 INPUT "R1 = ",R1
540 INPUT "R2 = ",R2
550 PRINT
560 PRINT "NEW FREQUENCY WOULD
    BE:";
    1.44/(C1*.000001*(R1+2*R2));"Hz"
570 RETURN
580 REM do monostable
    calculations
590 PRINT
600 PRINT "0.  END"
610 PRINT "1.  FIND T, GIVEN R
    AND C"
620 PRINT "2.  FIND R, GIVEN T
    AND C"
630 PRINT "3.  FIND C, GIVEN R
    AND T"
640 PRINT
650 INPUT "    CHOOSE: ",IN
660 PRINT
670 IF IN=0 THEN GOTO 140 ELSE
    ON IN GOSUB 720, 770, 820
680 PRINT
690 PRINT
    "C=";C1;"uF";TAB(15);"R=";R
    1;"ohms";TAB(30);"T=";T*1000;"msec"
700 PRINT
710 GOTO 580
720 REM FIND T, GIVEN R AND C
730 INPUT "R = ",R1
740 INPUT "C = ",C1
750 T=1.1*R1*C1*.000001
760 RETURN
770 REM FIND R, GIVEN T AND C
780 INPUT "T = ",T
790 INPUT "C = ",C1
800 R1=T/1.1*C1*1E+06
810 RETURN
820 REM FIND C, GIVEN R AND T
830 INPUT "R = ",R1
840 INPUT "T = ",T
850 C=T/1.1*R1*.000001
860 RETURN
870 REM PRINT ASTABLE VARIABLES
880 PRINT
890 PRINT
    "F=";F;"Hz";TAB(15);"C1=";C
    1;"uF";TAB(30);
900 PRINT
    "R1=";R1;"ohms";TAB(45);"R2
    =";R2;"ohms"
910 PRINT
920 RETURN
930 END
```

answer of 1.1 seconds.

In both the astable and monostable sections of the program, enter resistor values in ohms and capacitor values in microfarads. For example, 100 pF would be entered .0001. In the monostable section, time would be entered in seconds, although time is reported in milliseconds. For example, you would enter one millisecond as .001; the program would print it "1 msec."

Improvements

The program is very useful as it is, but some improvements could be made (they always can). First of all, in the astable mode it's sometimes necessary to know the duty cycle a combination of components will give. Doing the calculation is easy; the formulae are available in standard databooks.

A somewhat more complex improvement would be to have the program suggest only standard values for the resistors. One way to do that would be to create an array and fill it from DATA statements containing scaled standard values (1.0, 1.1, 1.2, . . . 9.1). Then after calculating a resistor's value, it would be scaled down to a number between one and ten, and the array would be searched for the closest match. That value would then be scaled up by the same amount the original value was scaled down. That's all there is to it!◀◍▶

COMPUTER-AIDED DESIGN OF LOUDSPEAKER ENCLOSURES PART I

Here's how to let your computer predict an enclosure's performance.

Michael Raleigh and Robert Raleigh

■The most-complex system is the ducted port enclosure. The other systems can be thought of as simplifications of this type. Figure 1 shows a cross section of a dynamic loudspeaker mounted in a ducted port enclosure. When driven at low frequencies, the behaviour of this system is simpler than it is at higher frequencies. The cone moves as a single, rigid mass. All the air inside the duct moves in unison, acting as another single mass. The volume of air within the enclosure acts like a spring, coupling the cone mass to the mass of air in the duct. The front of both the cone and the air in the duct experience a frictional drag due to the acoustic power they radiate. This effect is called the radiation resistance, and is frequency dependent. The program retains only the first term in the Taylor expansion of the Bessel function that gives this frequency dependence. A small additional mass is added to the cone and the duct by the effect of the outside air and, here too, we keep only the first term of the Taylor expansion. Additional springiness and resistance result from the cone surround and the coil spider. More resistance is sometimes included in such enclosures in the form of fiberglass batting lining the box, across the port, or behind the woofer.

When the simplifications described are applicable, a ducted port enclosure behaves much like the lumped parameter mechanical device shown in Figure 2. For this mechanical system comprised of masses, springs and dampers there are two electrical circuits composed of capacitors, inductors and resistors which exhibit analagous behaviour. They have the same governing equations with a renaming of the quantities

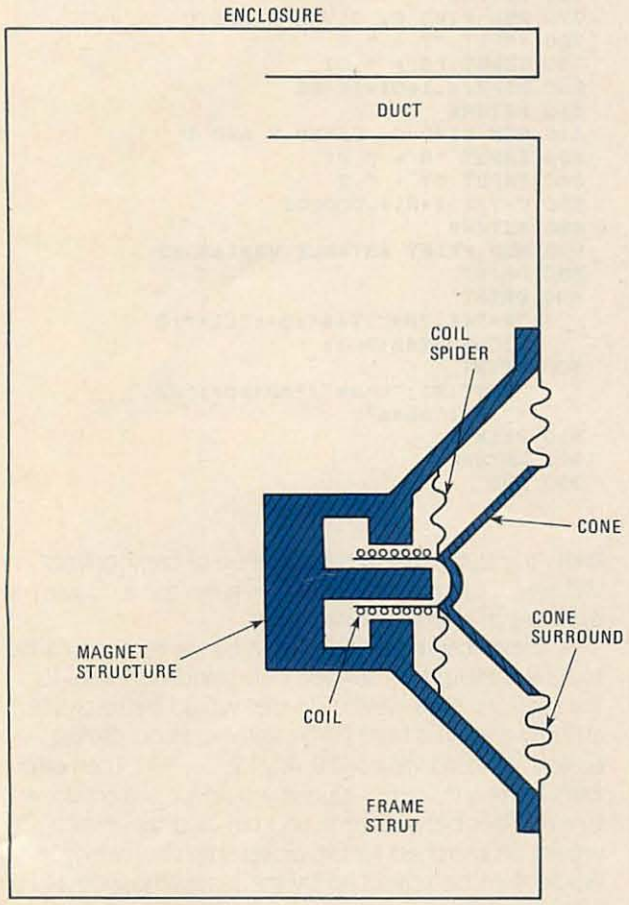


FIG. 1—CROSS SECTION of a dynamic woofer mounted in a ducted port enclosure.

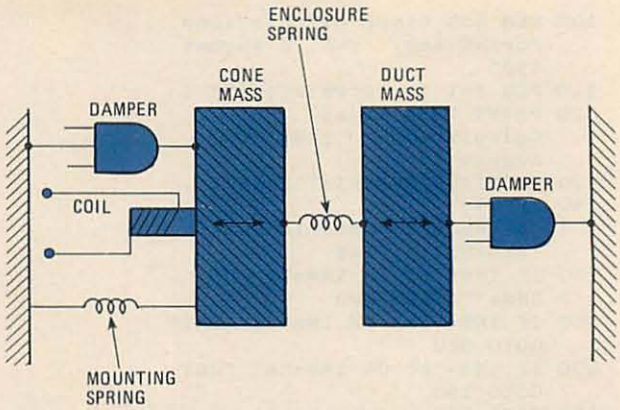


FIG 2.—MECHANICAL SYSTEM, equivalent at low frequencies, to the speaker shown in Fig. 1. Cone mass and the mass of air are assumed to move only in one direction, indicated by arrows. Coil applies oscillatory force to cone in this direction. Dampers are sources of mechanical resistance. One end of each damper and mounting spring has a fixed point of attachment.

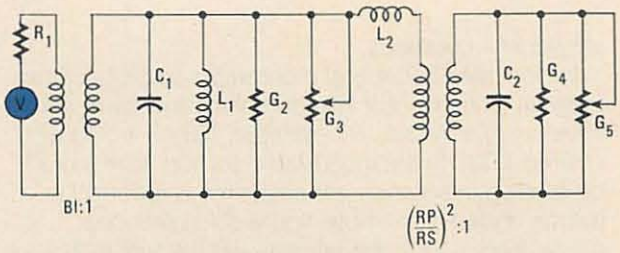


FIG. 3—ELECTRICAL CIRCUIT analagous to systems in Figs. 1 and 2. Corresponding parameters are: R1 = Coil resistance, C1 = Mass of cone and co-moving air, L1 = Compliance of cone mountings, G2 = Mechanical resistance of cone mountings, G3 = Radiation resistance of cone, L2 = Compliance of enclosure volume, RP = Port (duct) radius, RS = Speaker radius, C2 = Mass of air in duct and co-moving air, G4 = Mechanical resistance, G5 = Radiation resistance of duct.

involved. In Figure 3, you see one of those circuits which is equivalent to Figure 2. The equivalent quantities are as follows:

Voltage = Velocity
Current = Force
Capacitance = Mass
Inductance = Spring Compliance
Electrical Conductance = Mechanical Resistance

Each mass in Figure 2 has associated with it a capacitor to ground in Figure 3 whose voltage is numerically equal to the velocity of the mass. The force being applied to the mass equals the current flowing into the capacitor. The sources of this current (force) are the resistors (dampers) and inductors (springs) attached to the capacitor (mass).

The computer program assumes that a 1-volt AC source is attached across the coil. The program establishes a set of differential equations (the node equations) which describe the behaviour of the circuit in Figure 3. The assumption of a steady-state response causes these equations to take the form of a set of simultaneous algebraic equations in terms of complex variables. These are solved for a selection of frequencies between 15 and 250 Hz. Outputs from the program include the acoustic intensity one meter from the speaker (resulting from the vector sum of the woofer and port amplitudes and given in watts per square meter), and the current drawn at the speaker terminals (which is the admittance since we assume a one-volt input, given in mhos). The program asks only for fundemental system parameters and does so using prompts to guide the user. Quantities such as the radiation resistances as a function of frequency are calculated internally. The program is listed and may be checked by running the design example described. The tabular output for this case is also given.

Parameter measurements

There are several of the woofer parameters which must be determined experimentally. These include cone radius, DC coil resistance, the Bl product for the magnet-coil combination, the compliance of the cone mountings, the free resonance of the woofer and the mechanical resistance of the cone mountings. Let's talk about how to make these measurements and present typical numbers from a design example using a 12-inch woofer. We use MKS units exclusively.

The effective cone radius may be measured from the center line of the cone to the mid-point of the cone surround. This number will be less than the nominal radius of the woofer. In the design example, the effective cone radius is .125 meters (4.92 inches).

The DC resistance of the coil may be measured with a multimeter. For the design example, this was 5.3 ohms. (This number is not to be confused with the nominal AC impedance of eight ohms.)

The Bl product is the product of the magnetic induction (B) in the magnet gap, and the length of coil wire, (l) in the gap. B is measured in Teslas. The Bl product determines the force exerted on the cone for a given coil current. This product is measured, as shown in Figure 4, by placing the woofer face-up on a

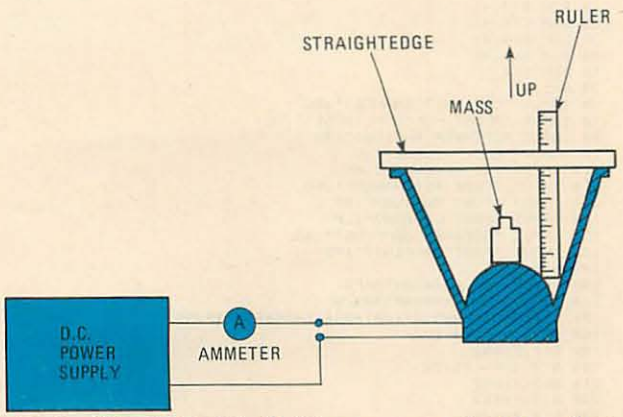


FIG. 4—ARRANGEMENT USED to measure the Bl product and the mounting compliance.

horizontal surface with a DC power supply and an ammeter attached to the coil. A straightedge is laid across the face of the woofer, and a light plastic ruler is stood upright in the cone so that the vertical position of the cone may be measured. Determine the position of the cone with no current in the coil, a known mass (M) is then carefully placed in the cone and current (I) necessary to,lift the cone and mass back to the unloaded position is determined. The Bl product is then given as:

$$C\left(\frac{M}{Nt}\right) = \frac{d\ (M)}{9.81 \times M\ (kg)}$$

The design example needed .237 amps to lift a .305 Kilogram mass back to the unloaded position, implying a Bl of 12.6 (T × M).

The compliance is also measured while the woofer is lying on its back with the straightedge and plastic ruler in place. The power supply is disconnected. The distance, d, which the mass causes the cone to depress is determined from the difference in the readings on the plastic ruler in both loaded and unloaded conditions. The compliance is then given by:

$$Bl\ (T \times M) = \frac{9.81 \times M\ (kg)}{I\ (A)}$$

For the design example, the .305 kilogram mass depressed the cone by .002 meters thereby implying a compliance of .000668 (Meters/Newton).

The free resonance and mechanical resistance of the woofer are determined using the arrangement shown in Figure 5. The bare woofer is suspended in a large room away from any objects or walls. We measure the current drawn and the voltage applied at various frequencies. At each frequency, we divide the current by the voltage to obtain the admittance. Note that if the same multimeter is used for both current and

Fig. 5—HOW WOOFER ADMITTANCE was measured. Admittance is used as a diagnostic to determine several parameters.

```
10 DIM G(4,4)
20 DIM C(4,4)
30 DIM B(4,4)
40 DIM A(4,4)
50 DIM T(4)
55 E=1
60 INPUT "COIL RESISTANCE?";RC
70 INPUT "MOUNTING COMPLIANCE?";MC
80 INPUT "SPEAKER RADIUS?";RS
90 INPUT "ENCL VOLUME?";V
100 INPUT "BL PRODUCT?";BL
110 INPUT "FREE RESONANCE?";FO
120 INPUT "PORT RADIUS?";RP
130 INPUT "PORT LENGTH?";LP
134 INPUT "SPEAKER DAMPING?";SD
136 INPUT "PORT DAMPING?";PD
140 B1=1/MC
150 C1=B1/(39.478418*FO*FO)
160 B2=1.43E6*RS*RS*RS*RS/V
170 C2=(3.83*LP+5.69*RP)*RS*RS*RS*RS/(RP*RP)
180 B(1,1)=-(B1+B2)
190 B(1,3)=B2
200 B(2,2)=-(B1+B2)
210 B(2,4)=B2
220 B(3,1)=B2
230 B(3,3)=-B2
240 B(4,2)=B2
250 B(4,4)=-B2
260 C(1,1)=C1
270 C(2,2)=C1
280 C(3,3)=C2
290 C(4,4)=C2
300 IS=BL/RC
305 PRINT#-2,TAB(5)"FREQ.";TAB(28);"POWER";TAB(48)"ADMIT."
306 PRINT#-2
310 F=10
320 FOR Z=1 TO 48
330 F=F+5
340 G0=.219*F*F*RS*RS*RS*RS
350 G1=G0+BL*BL/RC+SD
360 G(1,2)=G1
370 G(2,1)=-G1
375 G2=G0+PD
380 G(3,4)=G2
390 G(4,3)=-G2
400 FOR I=1 TO 4
410 FOR J=1 TO 4
420 A(I,J)=39.4784*F*F*C(I,J)+6.2832*F*G(I,J)+B(I,J)
430 NEXT J
440 NEXT I
450 GOSUB 1010
460 A0=D
470 FOR I=1 TO 4
480 T(I)=A(I,1)
490 A(I,1)=0
500 NEXT I
510 A(2,1)=-6.2832*F*IS
520 GOSUB 1010
530 A1=D
540 FOR I=1 TO 4
550 A(I,1)=T(I)
560 T(I)=A(I,2)
570 A(I,2)=0
580 NEXT I
590 A(2,2)=-6.2832*F*IS
600 GOSUB 1010
610 A2=D
620 FOR I=1 TO 4
630 A(I,2)=T(I)
640 T(I)=A(I,3)
650 A(I,3)=0
660 NEXT I
670 A(2,3)=-6.2832*F*IS
680 GOSUB 1010
690 A3=D
700 FOR I=1 TO 4
710 A(I,3)=T(I)
720 A(I,4)=0
730 NEXT I
740 A(2,4)=-6.2832*F*IS
750 GOSUB 1010
760 VA=A1/A0
770 VB=A2/A0
780 VC=-A3/A0
790 VD=-D/A0
792 IA=IS-VA*BL*BL/RC
794 IB=-VB*BL*BL/RC
796 IM=SQR(IA*IA+IB*IB)/BL
800 P=3.49E-2*(F^2*RS^4)
810 PS=P*((VA+VC)*(VA+VC)+(VB+VD)*(VB+VD))
880 PRINT#-2,TAB(5)F;TAB(25)PS;TAB(45)IM
900 NEXT Z
910 END
1010 D=0
1020 FOR I=1 TO 4
1030 FOR J=1 TO 4
1040 IF J=I THEN GOTO 1220
1050 FOR K=1 TO 4
1060 IF K=I THEN GOTO 1210
1070 IF K=J THEN GOTO 1210
1080 FOR X=1 TO 4
1090 IF X=I THEN GOTO 1200
1100 IF X=J THEN GOTO 1200
1110 IF X=K THEN GOTO 1200
1190 D=D+E*A(1,I)*A(2,J)*A(3,K)*A(4,X)
1195 E=-E
1200 NEXT X
1210 NEXT K
1215 E=-E
1220 NEXT J
1230 NEXT I
1240 RETURN
```

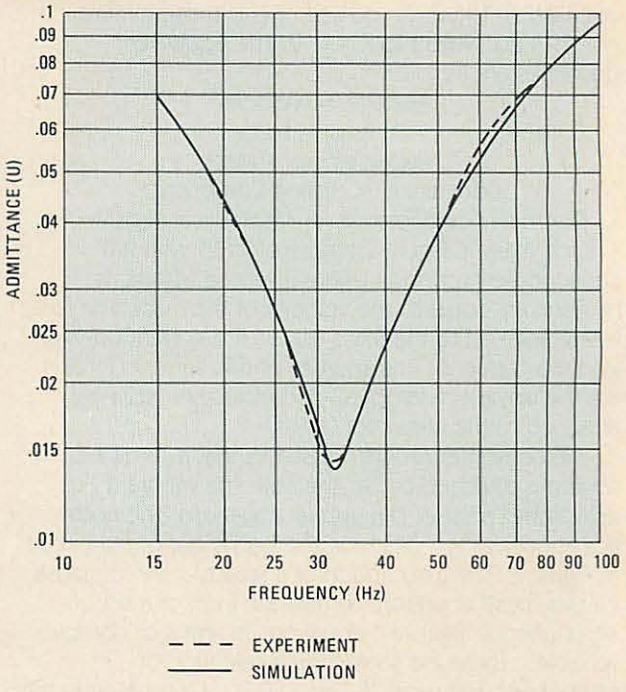


FIG. 6—MEASURED AND COMPUTER SIMULATED admittance of the woofer used as a design example in text. Curves represent behaviour of bare, unenclosed woofer.

voltage measurements, the low-frequency roll-off of that instrument is cancelled in the division of one quantity by the other. A graph of the admittance for our design example is offered in Figure 6. The free resonance is that frequency at which the minumum admittance occurs. (33 Hz for the design example.)

We determine the mechanical resistance by running the computer program with various assumed mechanical resistances until the computed admittance versus frequency matches the experimental results (Fig. 6). In the program we approximate suspending the bare woofer in a large room by assuming a very large enclosure volume (1000 cubic meters) and port dimensions (.001 meter radius, 1000 meter length) for which the port has no effect at any frequency of interest. The design example shows a good match between the computer result and the experimental measurement for an assumed mechanical resistance of 2.45 mechanical ohms.

Computer experiments with various enclosures

Continuing with the design example previously introduced, we use the measured parameters and compute the response for this woofer in several different enclosures. Figure 7 shows the response given by an infinite baffle of .2 cubic meters. For this run, the lack of a port is simulated by using a port radius of .001 meters and a port length of 1000 meters. As it happens, this is a rather lightweight woofer and does not perform well in a small closed box. The frequency response begins to roll off above 100 Hz.

We're sorry, but we've run out of space in this issue. This article will be concluded next month.